

Plug-in HEVs

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Plug-in HEVs - the Best of Both Worlds

- Fully functional EV (e.g. five days a week)
- AND a fully-functional engine-dominant HEV (for weekend trips)
- Contains all the features consumers love about EVs
- Plus the long range and large market potential of HEVs
- Unlike all other clean, advanced vehicles the primary infrastructure already exists – 120 V outlet in your garage each night (86% have access to a plug at home)
- Plug-in HEV is in-between a full size EV and no-plug HEV
 - Engine is smaller than no-plug HEV
 - Battery is bigger than no plug HEV (e.g. 6 kWh vs 3 kWh)

Plug-in HEV news

- CARB staff in April says Plug-in HEVs are the low cost way to comply with the Silver Category in the early years.
- CEC report in June finds Plug-in HEV 20 to have the highest cost-benefit ratio of all fuel substitution technologies
- CEC report also finds the Plug-in HEV does well.
- CEC report raises concern of lack of OEM
- OEM press conference for North American Plug-in HEV effort with EPRI, SCE and several agencies is slated for September 2003.

Other OEMs

- Nissan proposal to CARB in 2000 (Renault “de-facto ownership & control” of Nissan)
- Volvo and Mitsubishi may have been ahead of their time with plug-in HEVs advocated to CARB in 1995
- Recent OEM acknowledgements at various meetings that plug-in HEVs make sense in Europe
- Current or pending plug-in HEV projects with several OEMs (not public)
- EPRI - sponsored HEV Alliance includes participation by Toyota, Nissan, DC, VW, and Ford

HEVWG Study - Broad Consensus

- HEVWG Phase 1 – 3-year, \$2 million study sponsored by EPRI, CARB, SCAQMD, and utilities
- Comprehensive look at 2010 costs, prices, performance, market potential, consumer & societal benefits, commercialization barriers / incentives
- Unusually strong consensus document involving
 - CARB, SCAQMD, USDOE
 - GM, Ford
 - Research groups – ANL, NREL, UCD
 - EPRI, SCE, SMUD, NYPA
- Leading researchers such as Kalhammer, Frank, Browning, Unnasch and others. Used OEM's market research firm.

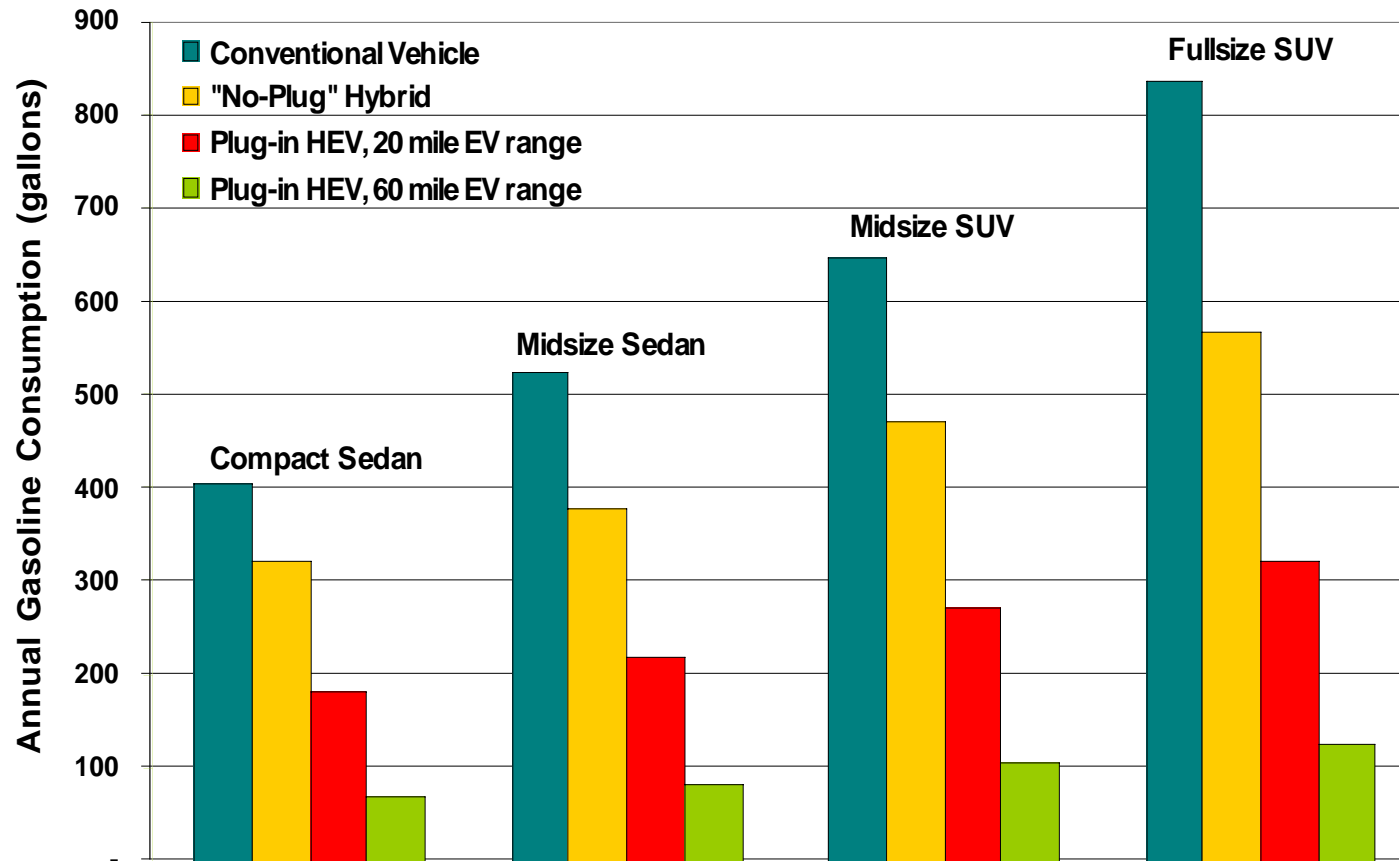
Societal Benefits HEV 20

20 miles all electric range per charge

- **= 40,000 – 75,000 ZEV miles with original NiMH pack**
- **Plus 100,000 or more ATPZEV gasoline ICE miles in power assist HEV mode**
- **30 - 40% less NOx and ROG than HEV 0**
- **20-30% less CO2 than HEV 0**
- **42% less petroleum (and trips to gas station) than HEV 0**

Source: HEVWG phase 2

Annual Gasoline Consumption



Source:
HEVWG

Up to 85% reduction in gasoline use and trips to gas station.

mid-size car O&M savings = \$5,000 over 100,000 miles.

Life Cycle Costs

Mid-size Car



-\$500

-\$1,200

Plug-In HEVs Will “Bridge the Gap”

- Provide real pure-ZEV miles. (e.g. 50,000 to 150,000)
- No significant technological hurdles. Can be available 2006-08.
- Incremental cost is manageable and very clean electricity grid infrastructure (120 V plugs) here today.
- Provide the next best thing to a BEV and address two big barriers – marketability and battery cost.
- Are the best way to reduce the cost of “energy” batteries needed by both BEVs and FCVs.
- Provide a “bridge” forward to FCVs, and a “path” back to BEVs.

Conclusions

- HEV 0s, PHEV 20s and PHEV 60s can reach cost parity with Conventional Vehicles at much higher battery prices (\$450 versus \$150/kWh)
- PHEV 20s and PHEV 60s can significantly reduce greenhouse gas and criteria emissions versus HEV 0s
- Because life cycle cost parity can be reached with PHEVs, emission benefits come at no cost to consumers (\$0/ton)
- Battery technology has advanced so costly battery replacements are minimized or avoided
- Battery leasing can turn upfront battery costs into operating expenses, making PHEVs even more attractive to consumers

Utility interest

- OEMs planning on producing Plug-in HEVs
- We can use this to meet the federal Energy Policy Act fleet mandates and use grid connected technology
- We need to understand the system impact of Plug-in HEVs, and encourage their charging off-peak
- Long-term, large scale adoption changes our 24-hour load curve. More efficient use of night-time power generation and the T&D system = downward pressure on rates.
- Mobile distributed generation to provide emergency back-up power and ancillary services to Cal-ISO.

Back-up Details

August 21, 2003

Additional Cost Savings (not included)

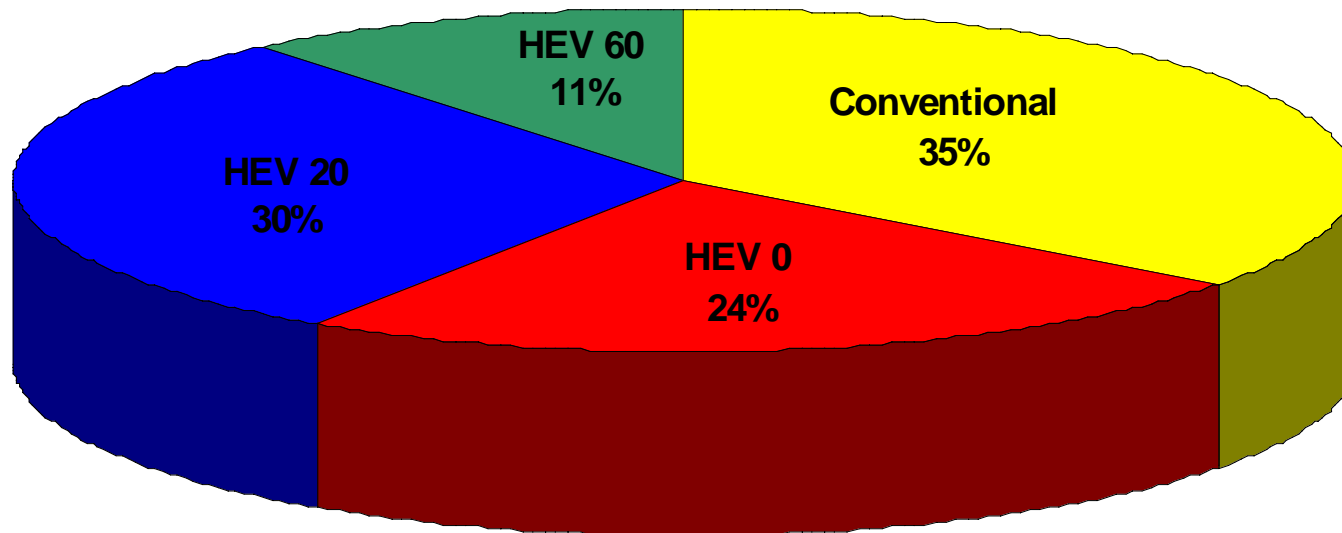
Vehicle Type	Estimated CAFE Benefit	Customer Willingness to Pay
HEV 0	\$500	\$2,250
PHEV 20	\$1,000	\$3,600 - \$4,000
BEV 40	\$2,000	\$2,000 - \$3,000

CAFE benefit based upon increased AMFA credits of HEVs, PHEVs, and BEVs

Willingness to pay based on HEVWG
Collaborative market research for the HEVs

Under the 2010 assumption that HEVs are common,
the market preference for plug-in HEVs is around 40%

Fullsize SUV - \$1.65/gal gasoline



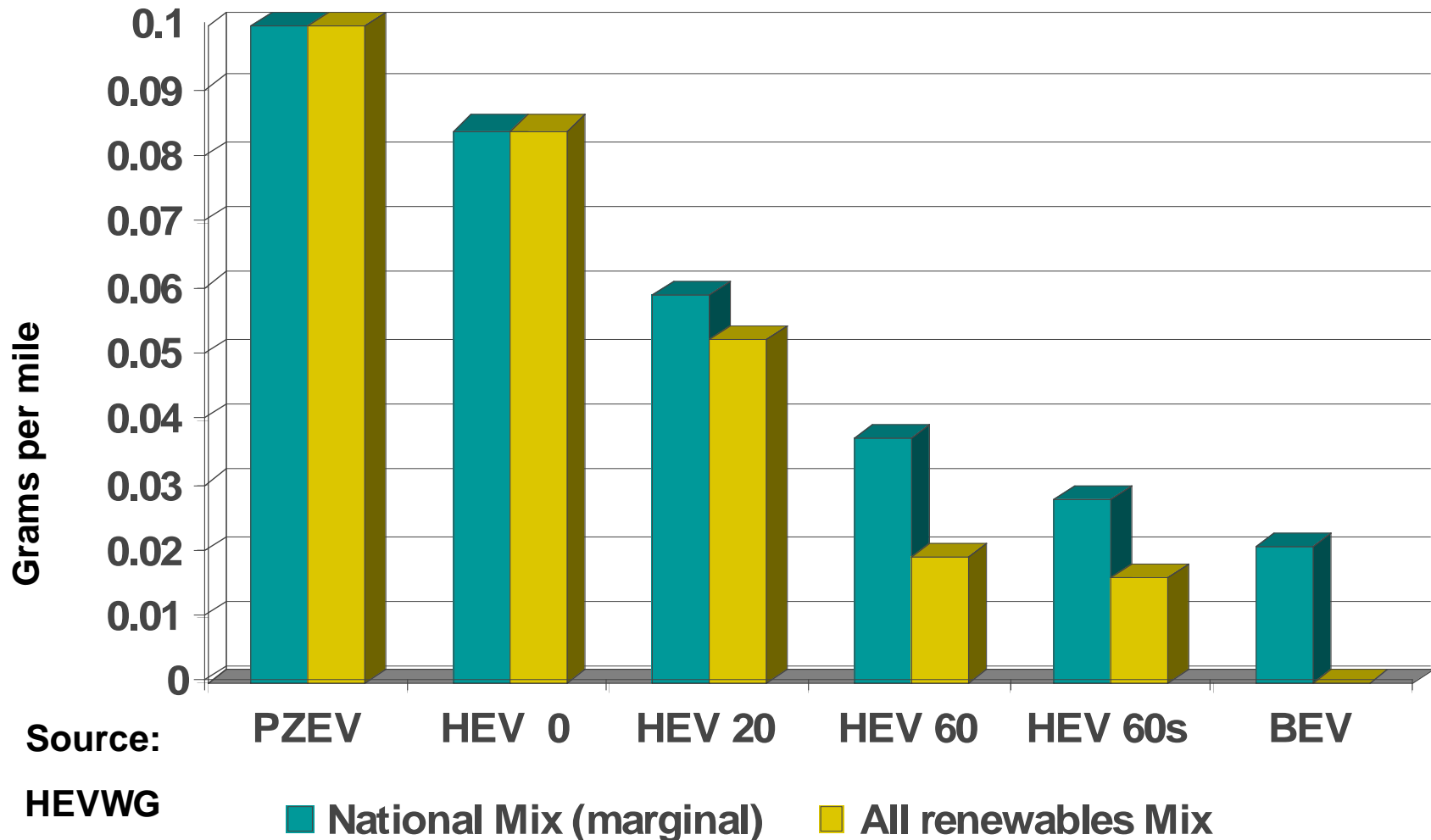
- ◆ Respondents were told that to get the benefits from the HEV20 & HEV60, they must plug-in each night and maybe upgrade their home electrical.
- ◆ Results also based on HEVWG finding that vehicle performance can be equal, and that battery costs can reach mass-market levels.

Why do people like the plug-in HEV and plugging in?

- Consumers understand plugging in is necessary to get benefits that are important to why they want the vehicle
 - Large fuel cost savings (50 – 80% savings, net after electric costs)
 - Significant maintenance savings (cost / time)
 - Avoiding gas stations (60 – 85 % fewer trips)
 - Convenience of full battery every morning
 - Reducing air pollution, global warming, foreign oil
 - Increased quietness / less vibration / fun to drive
 - Several other consumer benefits and features

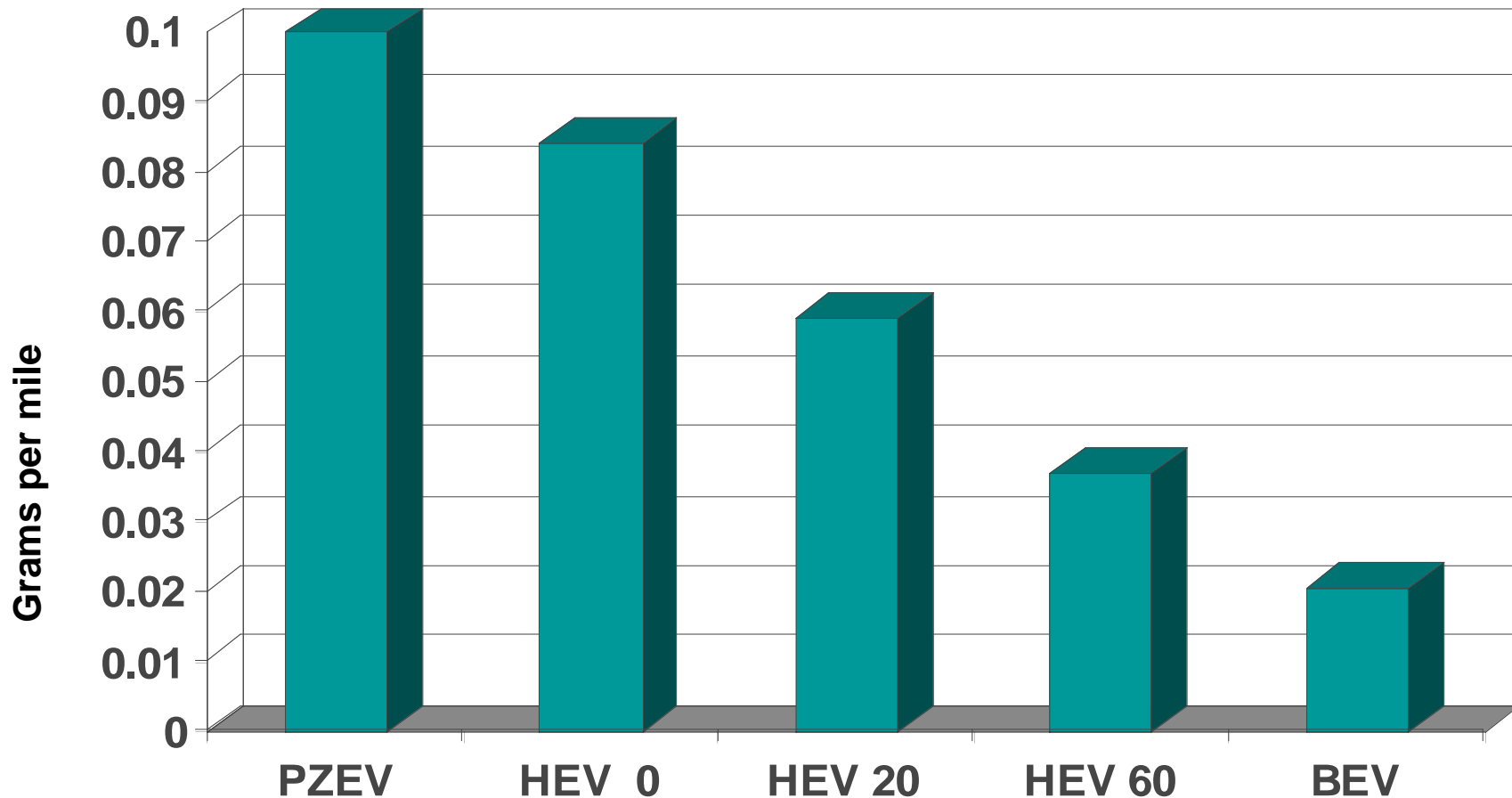
Source – HEVWG market research

NOx and ROG National Mix -- well to wheels mid-size sedan



All meet the zero-evap (0.012 g/m less than SULEV). But all cars including BEVs have 0.018 g/mi ROG from vinyl, cloth etc.

NO_x and ROG California Mix -- well to wheels mid-size sedan



Source: HEVWG

■ California Mix (Marginal)

All meet the zero-evap (0.012 g/m less than SULEV). But all cars including BEVs have 0.018 g/mi ROG from vinyl, cloth etc.

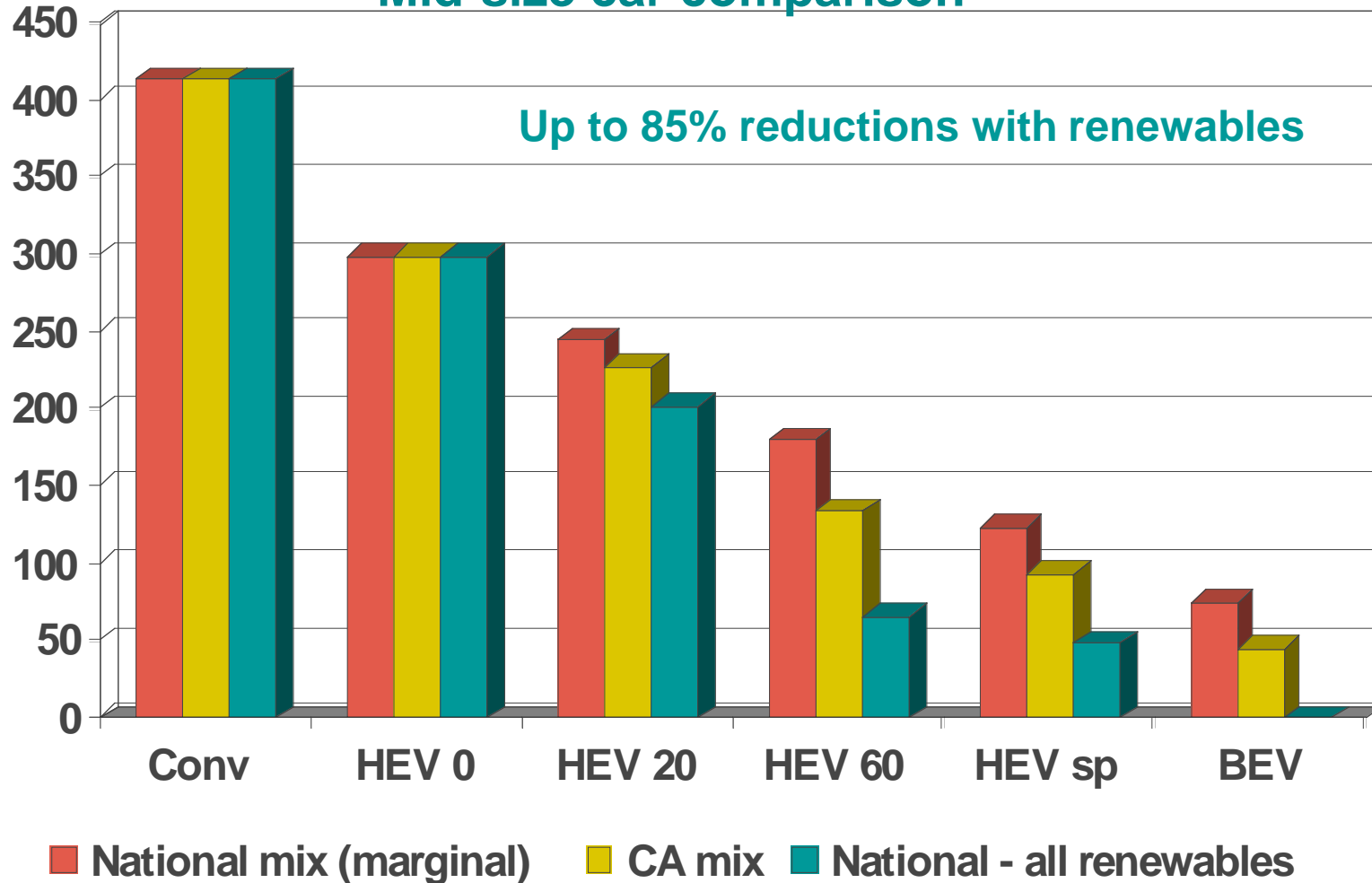
Local NOx and ROG Reductions Often Are Larger Still

- South Coast AQMD
 - Grams per mile is near zero for BEVs because any NOx increase from local power plants is off-set by reductions in other users under the cap and trade program (RECLAIM)
 - Plug-in HEV emissions much lower also in SCAQMD
- Purchasers and Owners of Renewable energy
 - E.g. green energy contracts
 - E.g. Owners of rooftop solar
 - Plug-in HEVs like BEVs benefit as the grid and non-grid electricity mix gets cleaner and moves to renewable energy
- By turning daily short trips into ZEV miles, plug-in HEVs reduce high levels of cold start emissions and the miles with the poorest fuel economy.

Greenhouse Gas Emissions well to wheel

National Mix vs California vs Renewables

Mid-size car comparison

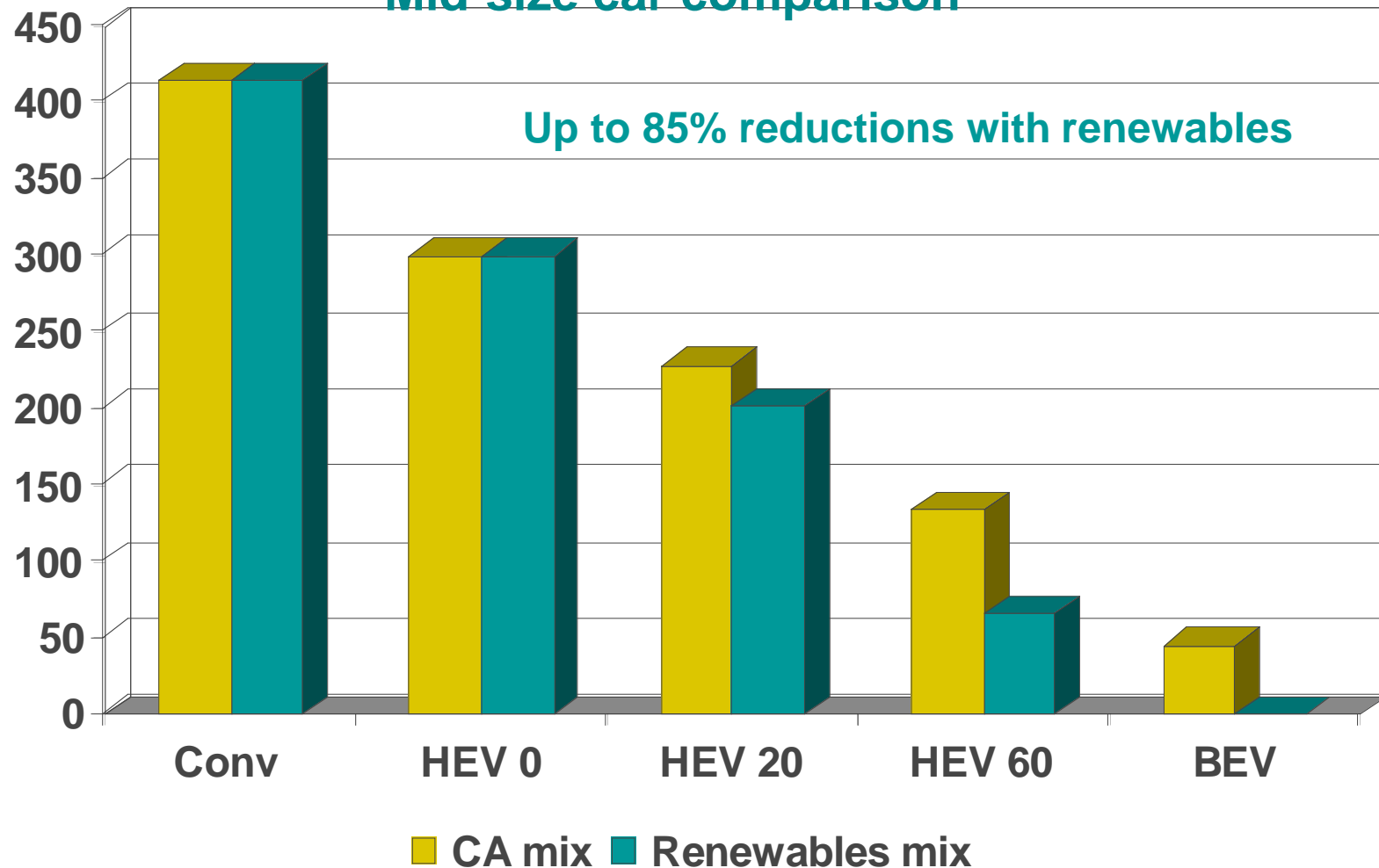


Source: HEVWG Includes adjustment for real world driving

Greenhouse Gas Emissions Well to Wheel

California vs Renewables

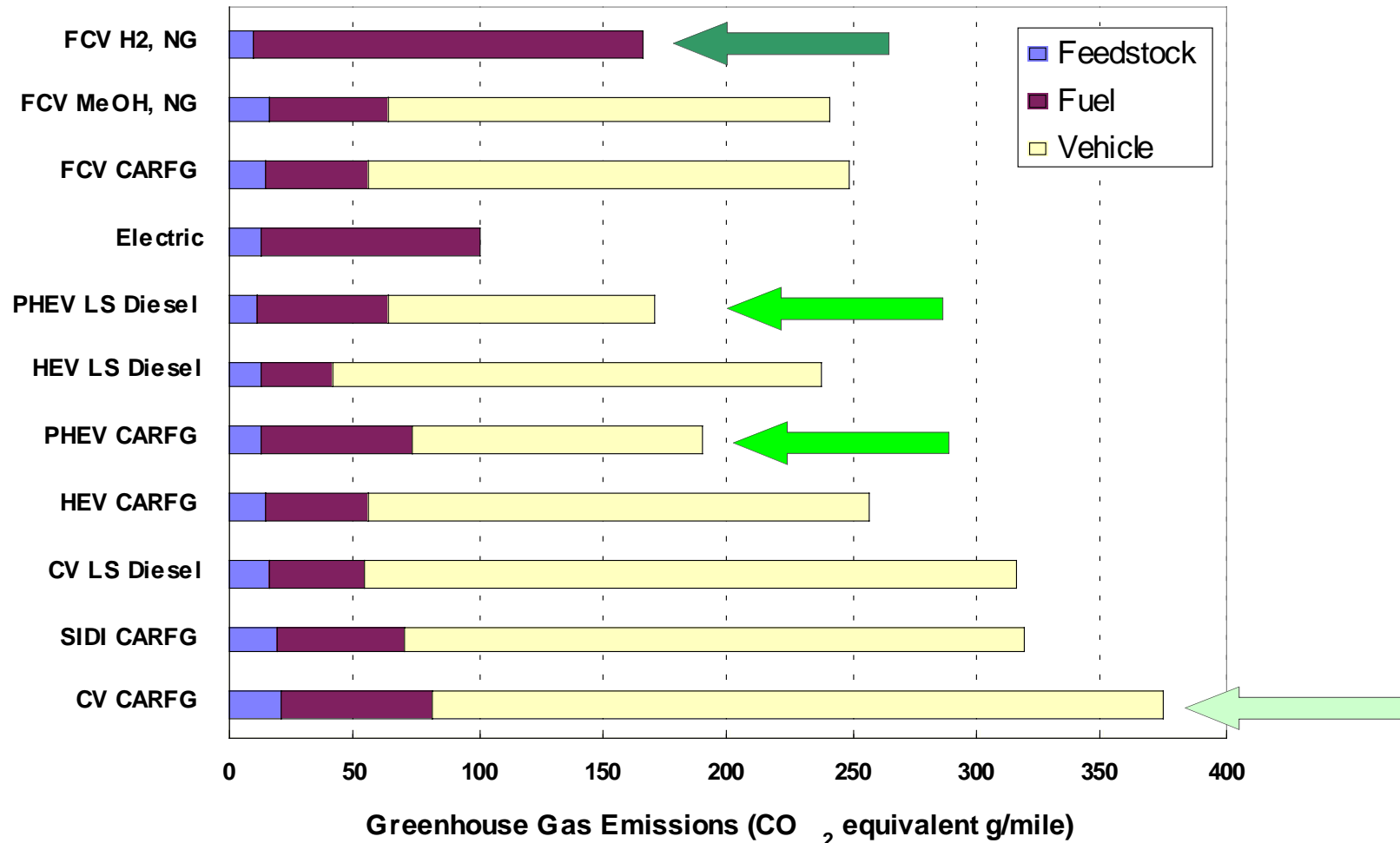
Mid-size car comparison



Includes adjustment for real world driving

Non-Redundant - Each Technology Represents Improvement Towards ZEV Goals

Full Fuel Cycle Analysis – 2025 Vehicle Technologies – CA Mix



Source: CARB Vehicles and CO2 Symposium March 2003.

HEVWG Cost Study Results Shows Incremental Cost & RPE is Manageable.

Vehicle Type	Retail Price Equivalent* (Argonne National Lab method)	RPE \$ difference
Compact Sedan	HEV 0 = \$16,400 HEV 20 = \$18,400	\$2,000
Mid-size Sedan	HEV 0 = \$21,370 HEV 20 = \$22,970	\$1,600
Mid-size SUV	HEV 0 = \$34,900 HEV 20 = \$37,300	\$2,400
Full size SUV	HEV 0 = \$42,040 HEV 20 = \$43,580	\$1,540

- Automaker pricing strategies to improve image, capture new markets, comply with CAFE, or maintain existing markets can help
- Existing and proposed tax policies can make a difference too.

*based on 100,000/ year volumes in next decade

Full size SUV Market Potential vs Price

No tax breaks or forward pricing

Assume 100,000 per year volume in next decade

Choice is CV or one HEV

Vehicle	Retail Price Equivalent Argonne National Lab method	Market Potential
Chevy Suburban 4WD	\$37,650	--
full size SUV HEV 0	\$42,040	45%
full-size SUV HEV 20	\$43,580	46%
full-size SUV HEV 60	\$48,570	30%

- O&M savings and/or pricing methods can pay for incremental cost of HEV 20 vs HEV 0
 - Federal tax breaks and pricing methods can achieve HEV 20 price in low volume near-term production
- Source :HEVWG

Mid size sedan Market Potential vs Price

No tax breaks or forward pricing

Assume 100,000 per year volumes in next decade

Choice is CV or one HEV

Vehicle	Retail Price Equivalent Argonne National Lab method	Market Potential
Lumina conventional	\$19,000	--
mid-size HEV 0	\$21,370	46%
mid-size HEV 20	\$22,970	47%
mid-size HEV 60	\$26,320	33%

- O&M savings and/or pricing methods can pay for incremental cost of HEV 20 vs HEV 0
- Federal tax breaks and pricing methods can achieve HEV 20 price in low volume near-term production

Societal Benefits HEV 60

60 miles all electric range per charge

- **= 105,000 – 150,000 ZEV miles with original NiMH pack**
- **Plus up to 70,000 – 100,000 PZEV gasoline ICE miles**
- **55 - 75% less NOx and ROG than HEV 0**
- **40 – 75% less CO2 than HEV 0**
- **78% less petroleum (and trips to gas station) than HEV 0**

Oh, What a Leader Toyota head wants company to be world's number one carmaker. Lexington Herald [Jan 29, 2003]

. . . The company [Toyota] also unveiled [at the Detroit Auto Show] a hybrid version of the Lexus RX 330 sport utility vehicle, which it said would be available within two years. By then, Toyota, which sold its 100,000th hybrid Prius compact in 2002, wants to sell 300,000 hybrids a year. Cho wants sales to reach **a million a year by 2010.** (Emphasis Added)

GM and HEVs

Richard Wagoner Jr. made “resoundingly clear that GM would not be left behind in the race with Japanese automakers for more fuel-efficient cars.” **Business Week, Feb 26, 2003.**

General Motors Corp. will announce today plans to begin producing as many as 1 million gas-electric hybrid cars and trucks a year — a challenge to the leadership role that Japanese carmakers have held in the race to bring such technology to the marketplace. **Los Angeles Times, Jan 6, 2003**

Respondents generally preferred plugging-in over going to the gas station

- Participants were asked which statement they agreed with more, using a 1 – 9 scale (1=Strongly Prefer Left, 9=Strongly Prefer Right):

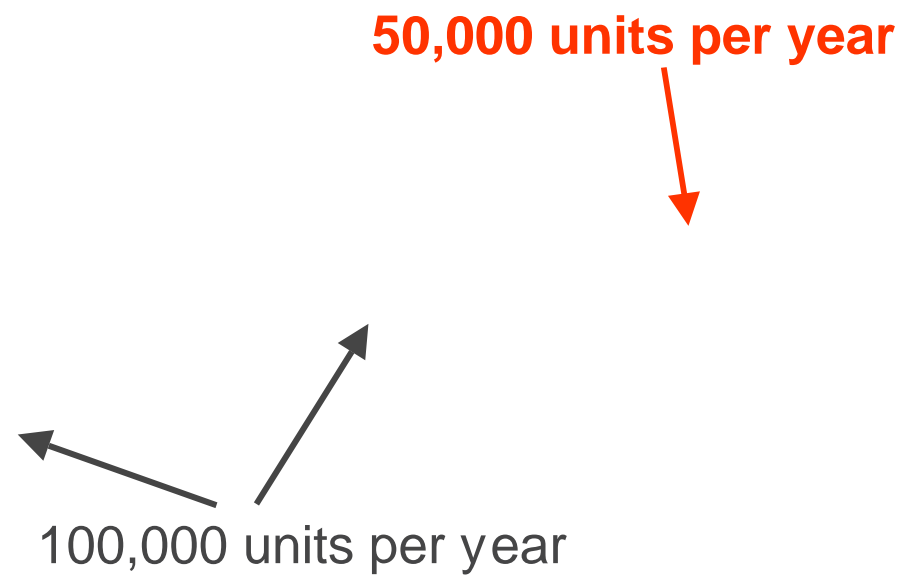
“I would prefer to fuel my vehicle with gas at the gas station”
VS.
“I would prefer to fuel my vehicle by plugging it in at home.”

- Results showed a strong preference for plugging in:

	All	Compact	Midsize	SUV	Luxury
<i>Average & Conf. Interval</i>	6.6 ± 0.2	6.5 ± 0.4	6.9 ± 0.3	6.5± 0.4	6.4± 0.4
Prefer gas (1 – 3)	4.1%	6.2%	1.1%	6.2%	5.9%
Neutral (4 – 6)	40.1%	40.6%	35.9%	44.8%	46.1%
Prefer plugging in (7 – 9)	55.8%	53.1%	63.0%	49.0%	48.0%

Cost Parity Curves

Mid-size Car



Half of all autos on the road on a typical day travel a total of 20 miles or less.

